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Eco-environmental Monitoring and Evaluation of the Tekes Watershed in Xinjiang Using Remote Sensing Images

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Abstract

Using the research results of eco-environmental evaluation for reference, this paper adopts three periods images which are respectively acquired in 1990, 2000, and 2010 as the main data sources. With the support of GIS technology, this paper quantitatively analyzes and evaluates the eco-environment situation and changes of the Tekes watershed by means of comprehensive index method and builds the thematic map of ecological environment factors. The results shows that the eco-environmental quality of the Tekes watershed has been in good condition, but in general, it tends to degrade slowly. With the comparison of the three periods assessment results , it is discovered that the eco-environment quality of 1990 is the best in Tekes watershed. There is a trend of decreasing by 4.0809 around 2000 year, but in 2010, it has improved slightly.

Keywords: Tekes river; watershed; Eco-environment; monitoring and evaluation; remote sensing

1. Introduction

Regional eco-environment is the core and foundation of regional economic sustainable development, its quality marks the capacity of regional economic sustainable development and harmonizes the relationship between social production and living environment[1]. Regional eco-environmental quality monitoring and evaluation is an important measure to realize the situation and major problems of regional

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eco-environmental quality, this can contribute to formulate and implement the plan of regional economic development.

The study of regional eco-environmental assessment begin in the 20th century, 80 years, up to now, more reliable and quantitative studies on comprehensive assessment of eco-environmental quality have been done and various methods have been employed to reveal the regional eco-environmental situation. there are some methods always used in researches such as AHP, the index evaluation method, fuzzy comprehensive evaluation method, artificial neural network evaluation method, matter element analysis and principal components analysis[2]. However, due to the complexity of the ecological environment, traditional environmental surveys and statistics appears significant limitations. With the application of the new technology such as RS and GIS in the eco-environmental evaluation, the research methods and depth was improved.

In this paper, Tekes watershed was selected as a case study area for investigation and quantitative evaluation. Based on the support of GIS and RS technology, eco-environmental quality in 1990, 2000, 2010 of Tekes watershed was analyzed by means of comprehensive index method, and its eco-environment responses were calculated and evaluated, which could be useful for local governments in planning eco-environment protection policies.

2. Study area

The Tekes watershed is located in the geographical range of 80°9′～83°43′E, 42°15′～43°36′N, including the main rives such as Tekes, Shata, Akeyaz, K-sou, etc., and involving five counties of Xinjiang Yili Hasak autonomous prefecture and Bayingolin Mongolian autonomous prefecture. It covers an area of 27671.6 km^2, which in our country totals 23168km^2. There is a complex topography and landform. The terrain decreases from southeast toward northwest, with the elevation between 920m and 6995m. The climate type is temperate continental climate. The mean annual temperature is about 4.2 °, mean annual precipitation is 400 mm, with most of the rainfall occurring between April and September, accounting for 80% of the total annual rainfall, and the average annual evaporation is 1358mm.

Tekes watershed is rich in mineral and hydropower resources, there are widespread forests and vast grasslands, which is known as “small chiangnan of xinjiang”[3]. Hence, it is the prominent base of cereals and oils, forestry and fruit industry and animal husbandry of xinjiang. In the recent 20 years, with the rapid development of socio-economics, some eco-environmental problems has appeared. For example, due to overgrazing, the functions of natural ecological grassland has degraded, in addition, natural geological disasters and soil erosion in research area have exacerbated because of the extensive development of some mines, which also impacts the water quality. Therefore, eco-environmental quality in the whole basin has damaged and even become one of the major factors restricting the sustainable development of the basin.

3. Research methods and Data processing

3.1. The establishment of evaluation index system

Indicators characterize a stable environmental state in the real situation and reflect changes in long- and short-term perspectives and they also characterize measures for bringing the environment back to sustainable development. An index is a quantitative characteristic, indicating the level of impact of different processes on the environment[4]. Therefore, the establishment of eco-environmental evaluation index system is the premise and key for this study, and many academics have been done a lot of studies on this issue. In those studies, when the author screened the indicators, such principles as systematic, scientific, maneuverable, dynamic and hierarchical characteristics were usually obeyed as common fundamentals. Referencing to the Technical Criterion for Eco-environmental Status Evaluation (HJ/T192-2006) published by the State Environmental Protection Administration, and considering in terms of the existing ecological problems of Tekes watershed, this paper selected biological abundance, vegetation coverage, water-network density, land retrogression and environmental quality as the eco-environmental evaluation indexes[5]. The result was denoted as ecological index (EI) in this paper, which number range is between 0 and 100. It can be summarized by the following equation:

$$EI=\sum K_i B_i=0.25EI_b+0.2EI_v+0.2EI_w+0.2EI_l+0.15EI_e \quad (i=1,2\ldots n) \tag{1}$$

Where B_i is the eco-environmental evaluation indicator, and K_i expresses the corresponding weight and n is the number of indicators used for evaluation. EI_b, EI_v, EI_w, EI_l, EI_e represent separately the biological abundance, vegetation coverage, water-network density, land retrogression and environmental quality.

In order to compare the eco-environmental quality of Tekes watershed, EI calculated based on the step 1 was divided 5 levels in this paper, they are given in table 1.

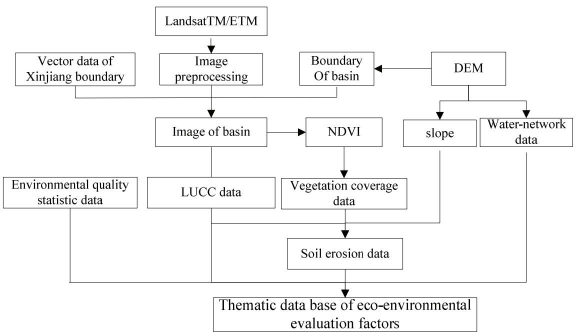
Table 1. Classification of eco-environmental quality in Tekes watershed

classification	best	good	normal	poor	poorer
EI	⩾75	55～75	35～55	20～35	⩽20

3.2. Data sources and processing

The materials used in this paper include LandSat5 TM and LandSat7 ETM+ images which are respectively acquired in 1990, 2000, and 2010 with the resolution of 30m as the main data sources. Each periods images refers to five scenes that are available from June to October, and the cloud cover is less than 8%. There are eight scenes of SRTM DEM supplied by CGIAR-CSI website with the resolution of 30m, and the vector data of Xinjiang provided by DIVA-GIS website. In addition, ILI Kazak autonomous prefecture statistics yearbook (1990,2000,2010) and some economic and social data are employed in this paper.

According to the eco-environmental feature of Tekes watershed, this paper extracted the eco-environmental evaluation factors based on ERDAS 9.2, ENVI 4.7 and ArcGIS 9.3, and built the thematic data base of eco-environment factors[6-8]. The technological program of data processing is described as figure 1 and the thematic maps are showed as figure 2-4.



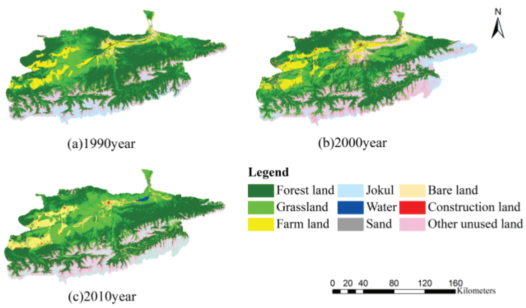


Fig.1. (1) The technological program of data processing; (2) The distribution map of LUCC of Tekes watershed

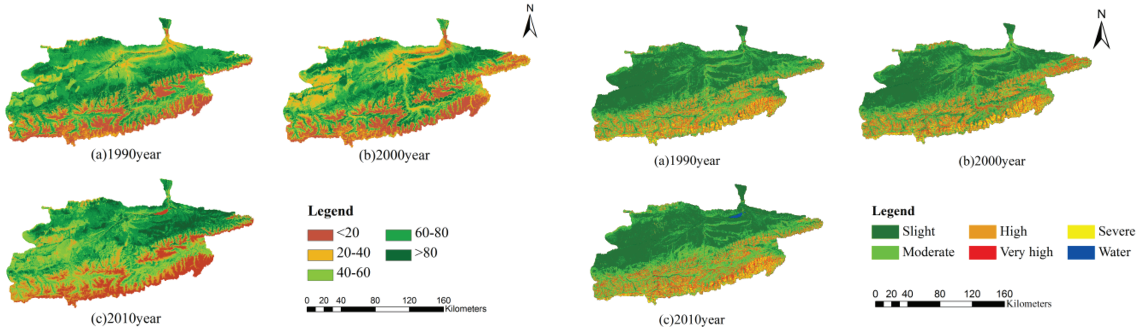


Fig.2. (1) Gradation of vegetation coverage of Tekes watershed; (2) Distribution of soil erosion types of Tekes watershed

4. The calculation of Evaluation index

According to the technical criterion for eco-environmental status evaluation, the eco-environmental evaluation indicators were calculated by following formulas:

(1) The calculation of biological abundance:

$$EI_b=A_{bio}\times[(0.35\times A_{for}+0.21\times A_{gra}+0.28\times A_{wat}+0.11\times A_{far}+0.04\times A_{con}+0.01\times A_{un})/A_{Tek}] \quad (2)$$

Where A_{for}, A_{gra}, A_{wat}, A_{far}, A_{con}, $A_{un,}$ A_{Tek} stand for the area of forestland, grassland, water, farmland, construction land , unused land and Tekes watershed, respectively.

(2) The calculation of vegetation coverage:

$$EI_v=A_{veg}\times[(0.38\times A_{for}+0.34\times A_{gra}+0.19\times A_{far}+0.07\times A_{con}+0.02\times A_{um})/A_{Tek}] \quad (3)$$

(3) The calculation of water-network density:

$$EI_w=(A_{riv}\times river\ length+A_{gra}\times lake\ area+A_{res}\times water\ quantity)/A_{Tek} \quad (4)$$

(4) The calculation of land retrogression:

$$EI_l=A_{ero}\times[(0.05\times A_{sli}+0.15\times A_m+0.2\times A_h+0.25\times A_e+0.35\times A_{sev})/A_{Tek}] \quad (5)$$

Where A_{sli}, A_m, A_h, A_e, A_{sev} denote separately the area of slight erosion, moderate erosion, high erosion, very high erosion and severe erosion.

(5) The calculation of environmental quality:

$$EI_e=0.6\times(100-A_{so2}\times so_2\ emissions/A_{Tek})+0.4\times(100-A_{sol}\times solid\ waste\ emissions/A_{Tek}] \quad (6)$$

In those formulas， A_{bio}、A_{veg}、A_{riv}、A_{lak}、A_{res}、A_{ero}、A_{so2}、A_{so1} are the normalized coefficients of biological abundance index, vegetation coverage index, river length, area of lake or reservoir, water quantity, land retrogression index, SO_2 emissions and solid waste emissions, respectively. According to the values of national normalization coefficient in 2000，their values were taken 400.62, 355.24, 46.43, 17.88, 61.42, 146.33, 0.06, 0.07, respectively.

According to above formulas (1-6), this paper calculated the EI in 1990, 2000 and 2010 of Tekes watershed, they are given in the following table 2.

Table 2. The eco-environmental quality index of Tekes watershed

Year	EI	Biological abundance	Vegetation coverage	Water-network density	Land retrogression	Environmental quality
1990	60.3122	89.9389	94.7084	15.9131	18.0924	80.5643
2000	56.2313	81.4501	86.8382	15.9189	18.8630	76.9649
2010	57.5745	84.6629	91.5150	15.9740	18.2834	76.4440

According to the table 2, dynamic changes of eco-environmental quality index of Tekes watershed can be obtained, as showed in Table 3. The positive number indicats that the eco-environmental quality is improved while the negative number is the opposite.

Table 3. Dynamic changes of eco-environmental quality index of Tekes watershed

dynamic change of EI	1990	2000	2010
1990	0.0000	-4.0809	-2.7377
2000	4.0809	0.0000	1.3432
2010	2.7377	-1.3432	0.0000

5. Results and discussions

(1) The eco-environmental quality index of Tekes watershed(table 2) showed that it was embodied a high degree of consistency among eco-environmental quality index, biological abundance and vegetation coverage. In general, it fell and then picked up during the study period, which was mainly caused by the dynamic change of land use. From 1990 to 2000, the areas of forest land and grass land decreased by 2145 km^2, 58.3km^2, respectively. But the areas of construction land and agricultural land increased year by year during the same period, especially the construction land which had an increasing rate of 14.65%. Under the guidance of regulations on conversion of farmland to forests or grassland, the area of grassland had increased 1049.1km^2 by 2010. But the forestland remained in the declining state, in that the area of plantation increased was far less than that natural forest reduced.

(2) Water-network density index of Tekes watershed was gradually ascend. The increasing mean annual temperature and melting snow and ice were mainly responsible for it. In addition, the large-scale farm water conservancy construction was carried out, which improved the capacity of farmland irrigation and drainage and the regional water resources total quantity. Especially in 2006, Qiafuqihai hydropower station was completed, it increased the area of reservoir and agriculture irrigation, and also improved the regional biodiversity. According to the survey, the regional irrigated area was extended due to the reservoir, and the density and biomass of zooplankton in Qiafuqihai reservoir was 11391 ind/L and 2.79 mg/L, respectively[9]. which improved the eco-environment quality of the Tekes watershed.

(3) Farming and animal husbandry was taken as the main economic backbone in Tekes watershed. There were no large pollution distribution. With the development of urbanization and industrialization,

the damage to eco-environment could restore through self-purification. Hence, the change rate of regional environmental quality index was little.

(4) To sum up, the eco-environmental quality of Tekes watershed was in a good state during the study period, it is suitable for human survival with higher vegetation coverage and richer biodiversity. the eco-environmental quality in 1990 was the highest with 60.3122, it dropped 4.0809 from 1990 to 2000, which indicated that deterioration of general eco-environment was slightly (by 6.67%). From 2000 to 2010, the dynamic degree of eco-environmental quality index was tiny, only 1.3234, and has been in the critical state between good and general. Consequently, the human activities that have negative influence on the eco-environment quality must be regarded highly.

6. Conclusion

In this paper, RS and GIS are applied to obtain the data of LUCC, vegetation coverage, water-network and soil erosion. On the basis of these data and the method of comprehensive index evaluation, the eco-environmental index is set up to evaluate the dynamic change of eco-environment of Tekes watershed and gets a satisfactory result. This will have certain reference value for realizing the environment state and making the plan of economic development.

In addition, this paper have some insufficient. For instance, the normalized coefficient of each evaluation index employs the national value, this used in small scale is inappropriate; Due to the resolution of remote sensing image and individual subjective factors, the accuracy of land classification in this paper needs to be improved; because the dynamic change and influence factors of eco-environment are complex and relativity, this study received the general characteristics of the eco-environment in the study area between 1990 and 2010, but it is still in the pre-study period and need further detailed analysis in future research.

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